Spare RFQ Overview, Status, and Plans

Presented at the

Accelerator Advisory Committee Review

Yoon Kang
Electrical & RF Group
Research Accelerator Division

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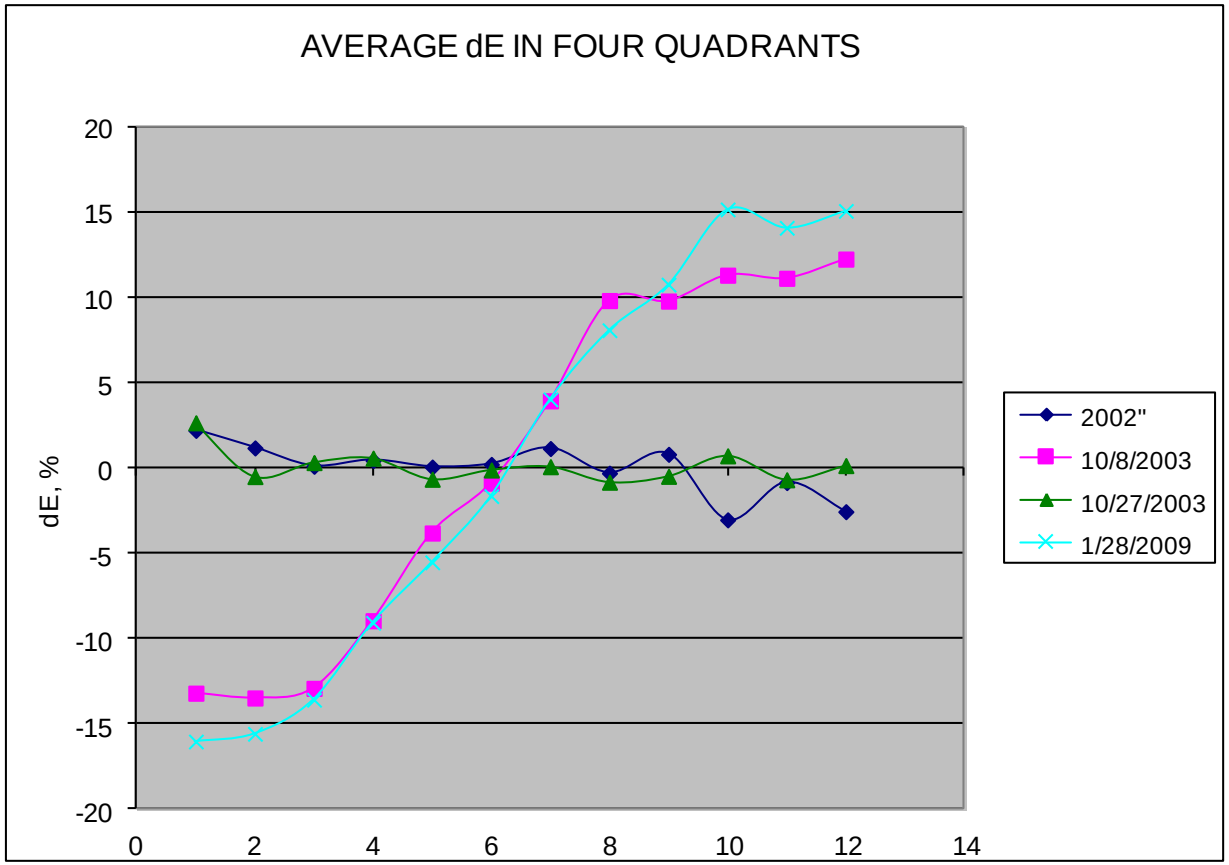
Overview

- Retuning of RFQ performed for sudden changes in frequency and field distribution
  - Resonant frequency shifted by -400 Hz and the field distribution changed by ±15% (9/23/2003)
  - Resonant frequency shifted again by -230 kHz and the field distribution changed (1/26/2009)
- Started writing equipment specification (7/2009)
- Equipment specification was prepared and delivered to potential vendors (10/2009)
- Supplier selected based on the track record, capability, and pricing (4/2010)
- Design completed with reviews and manufacturing started (3/2011)
- Maintain the beam dynamics of the original SNS RFQ design
  - Vane tip modulation data was supplied as the core design requirement
  - Supplier was asked to have structural design and prototyping
- Construct a robust structure for direct replacement spare with minimal modifications on the SNS linac
  - RF frequency, power, cooling, vacuum, and physical dimensions to be satisfied

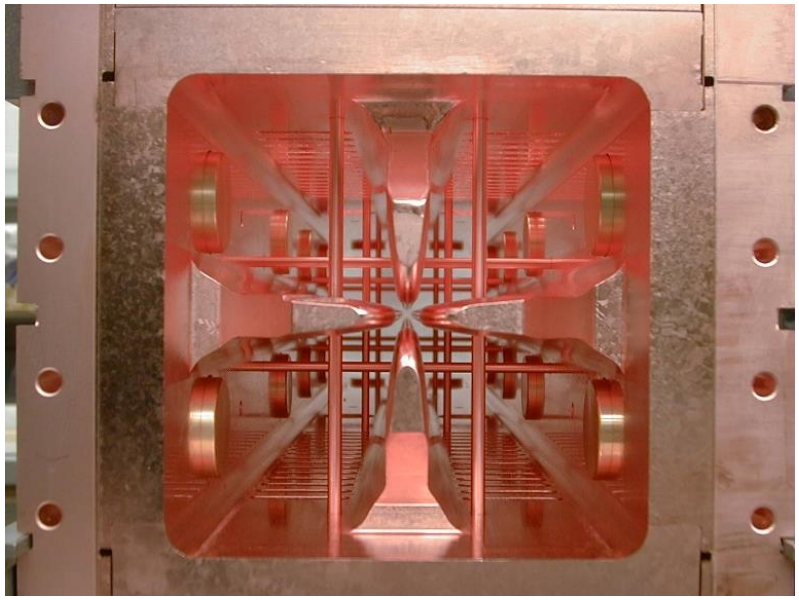
Field Measurements (Average of Fields)

Existing RFQ



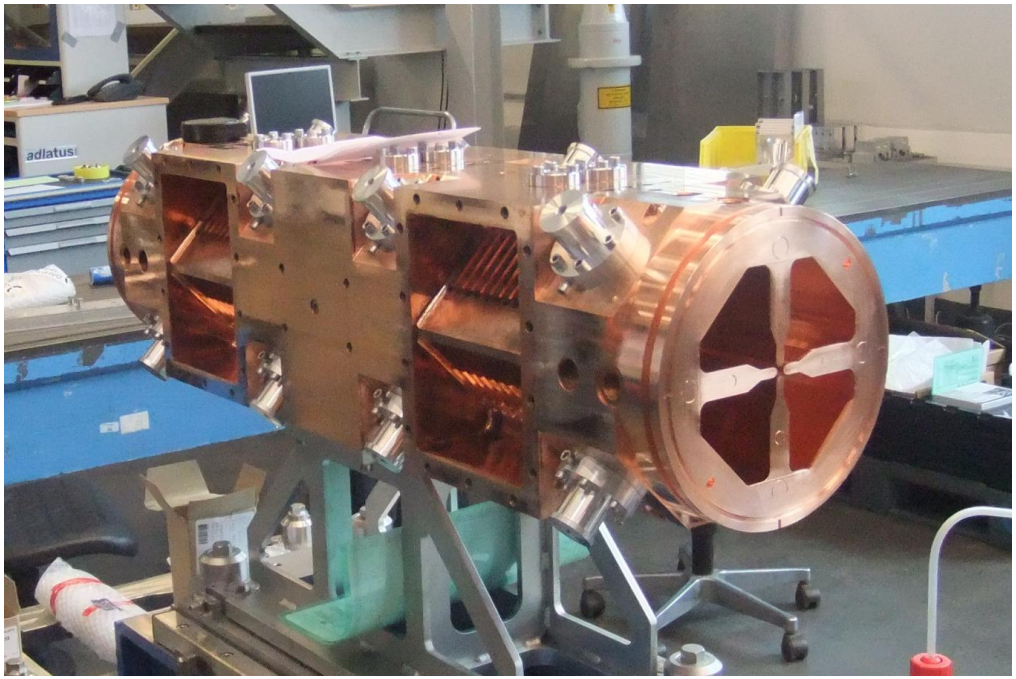
- 9/21/2003, during maintenance outage period, RFQ resonance frequency was found with -400 kHz shift
- Field measurement showed ±15 % deviation along the structure
- RFQ was retuned
- 1/26/2009, again during shutdown, the resonance frequency shifted by -230 kHz
- Field distortion was similar to what experienced in 2003
- RFQ was retuned

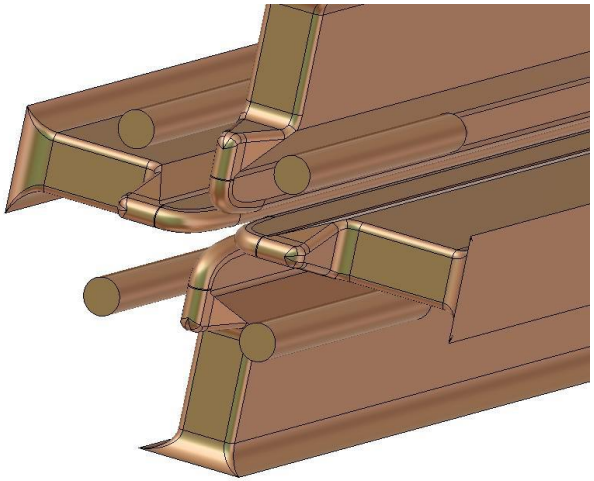
Comparison of RFQ
(Existing RFQ)

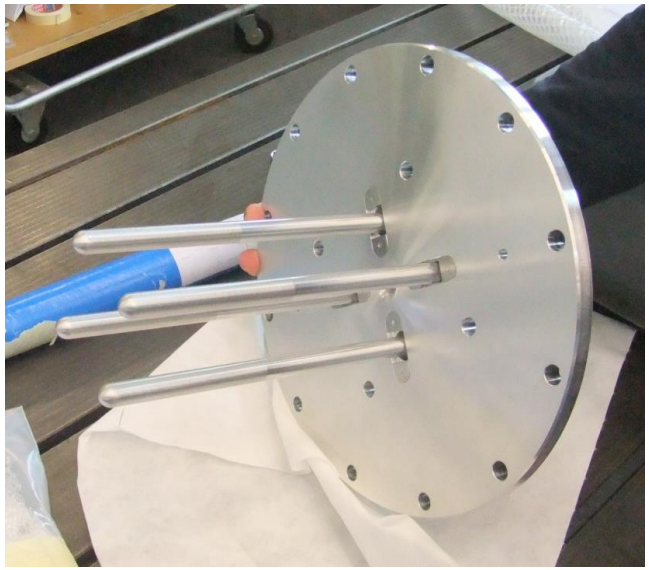


- 3.7 m length in 4 sections
- Two layer copper structure with GlidCop exoskeleton for strength
  - Strength needed to use minimally supporting kinematic structure design
- 4 vane type with PISL for dipole stabilizing
- 80 slug tuners (1.4” dia each) and 46 field probes
- 2 input couplers (originally 8)

Comparison of RFQ
(New spare RFQ)

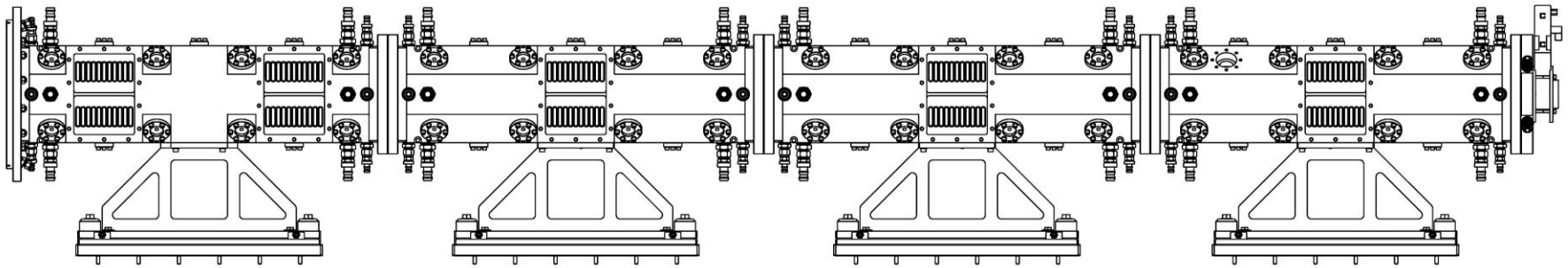






- 3.7 m length in 4 sections
- 4 vane type with end wall rods for dipole mode stabilizing
- Robust uniformly supported structure
- 64 slug tuners (1.4” dia each) and 48 field probes
- 2 coaxial input couplers

Spare RFQ Construction



- Vane tip modulations are the same to the existing system for the unchanged beam dynamics
- Robust vacuum pumping
  - 4x 1700L/sec turbos in module 1
  - 6x 2500L/sec cryopumps in Modules 2, 3, and 4
- Robust uniformly supported structure for stability
- Single layer Copper structure RFQ with octagonal cross section
  - Vane tip movement: 48.1 kHz/μm, (50 kHz/μm existing)
  - Body sensitivity: 6.0 kHz/μm, (2.3 kHz/μm existing)
  - Deformation due to vacuum: -18 kHz, (-119 kHz existing)
- End wall rod dipole stabilizing with improved Q factor
  - Qo = 8000, (7400)

RF Power Dissipation

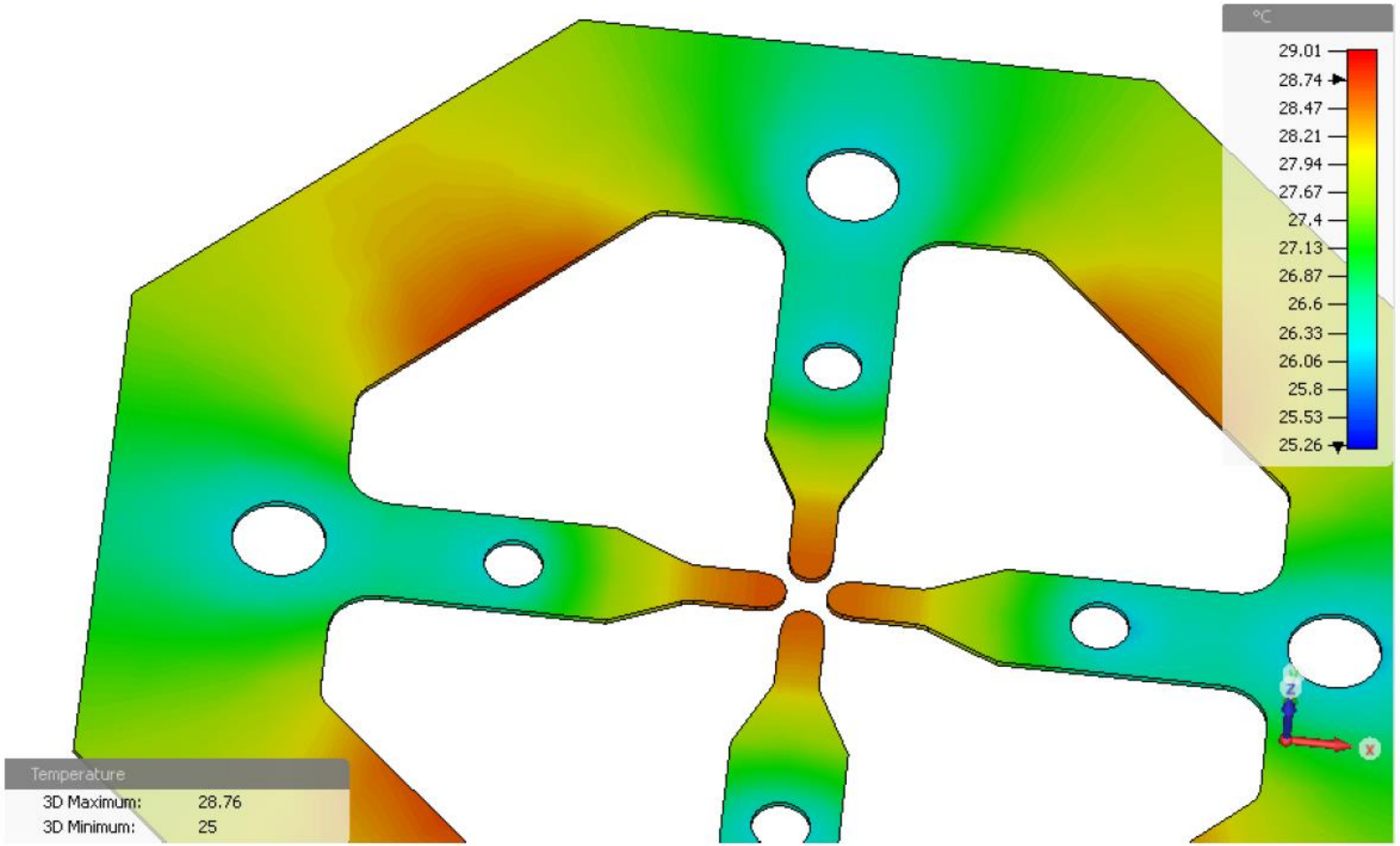
	Quantity	Unit	Power
Nominal wall power		W/mm	112
Resonator length		mm	3,736
Nominal wall power		kW	419.8
Slug tuner power dissipation	64	kW	6.5
Vacuum port grid	10	kW	35.4
End flange	2	kW	0.801
Dipole stabilizer rod	8	kW	3.63
Vane undercut	8	kW	1.33
Total structure power (Peak)		kW	467.4
Total structure power (Ave)		kW	37.4
Beam power (60 mA)		kW	150.0
Coupler power	2	kW	308.7 (617.4)

Cooling Design (I)

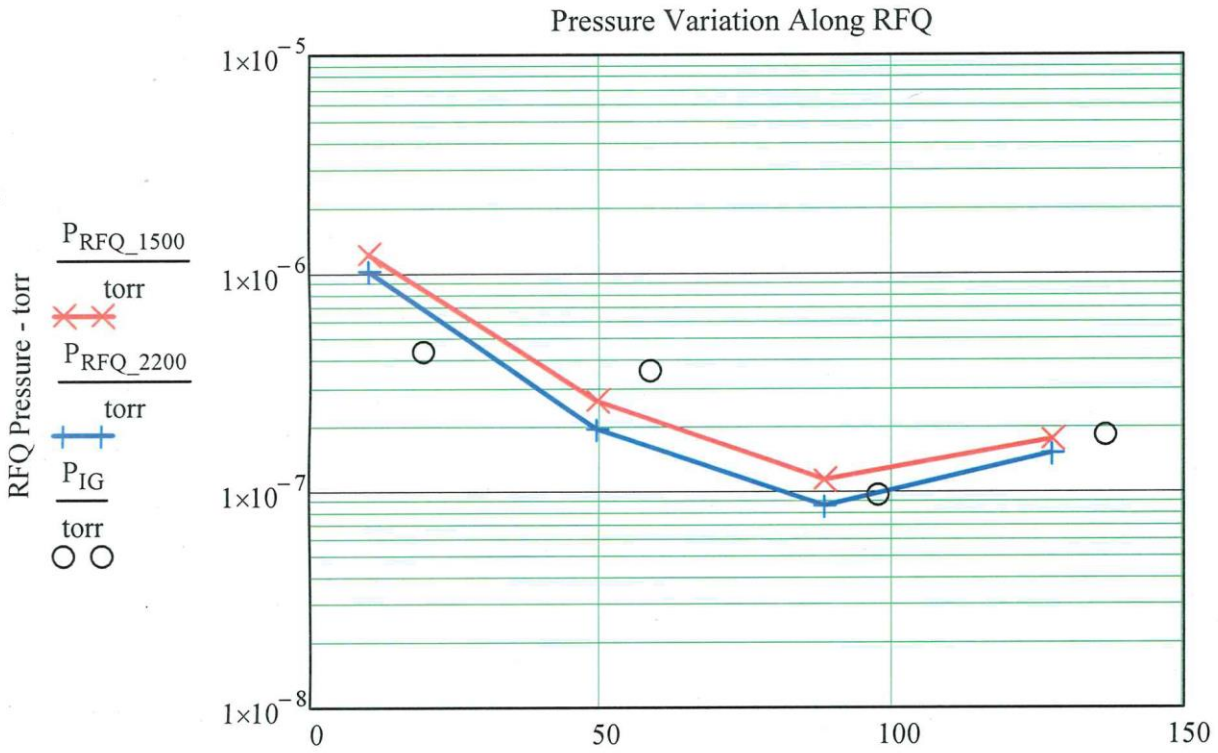
	Unit	Vane tip	Body	End plate
Number of channels	ea	4	4	2
Number of series	ea	4	4	2
Flow rate	L/min	7.5	18.1	4.5
Flow velocity	m/sec	1.6	1.5	1.5
Delta T	°C	2.56	1.44	0.95
Cooling channel diameter	mm	10	16	10
Chiller requirement, flow rate	L/min	121	290	18
Chiller requirement, heat removal	kW	21.4	29.0	1.2
Sensitivity	μm/°C	0.62	1.24	
	kHz/°C	29.8	7.44	

Cooling Design (II)

Full power operation with cooling (20°C inlet)



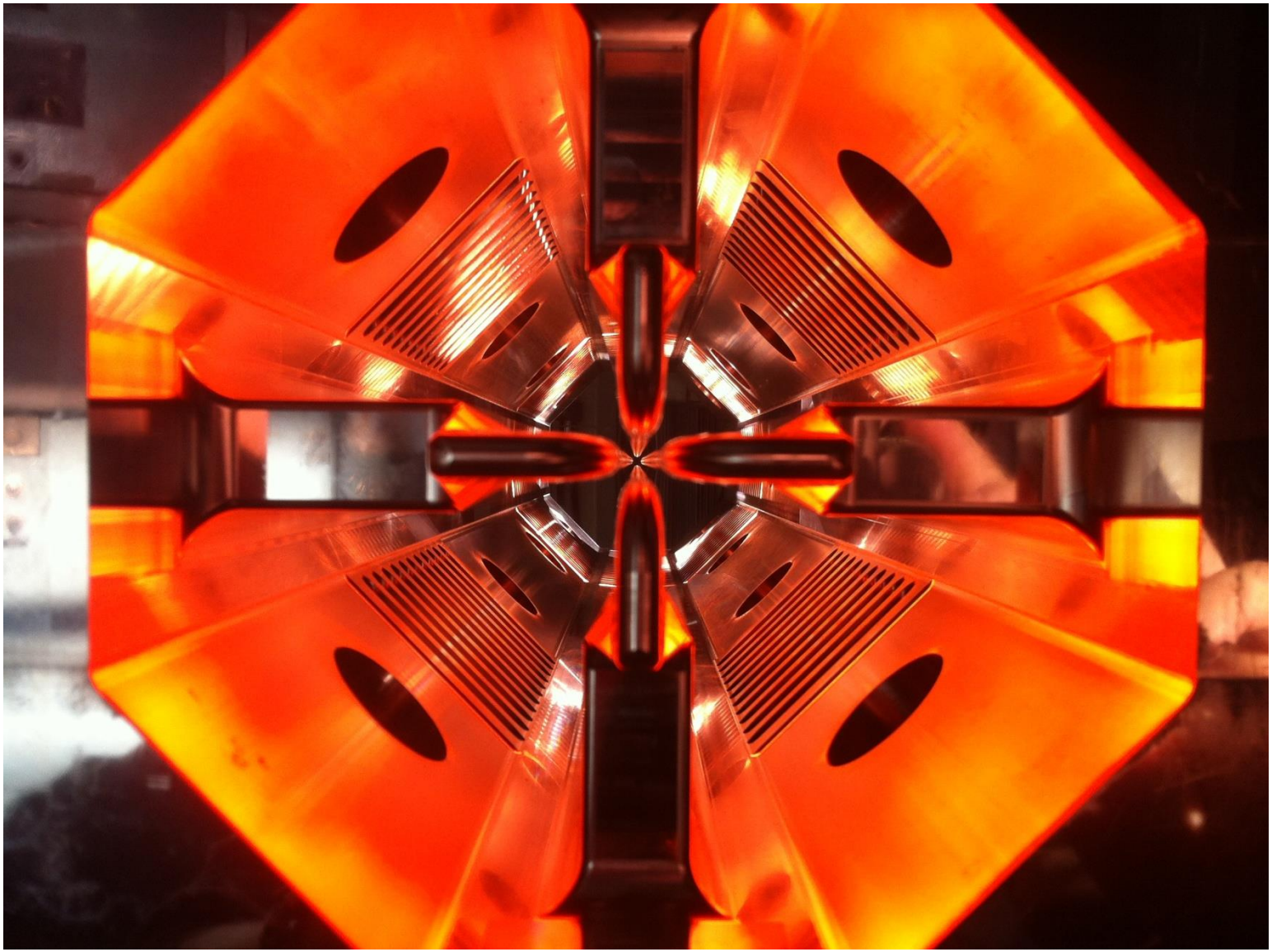
Vacuum Estimation



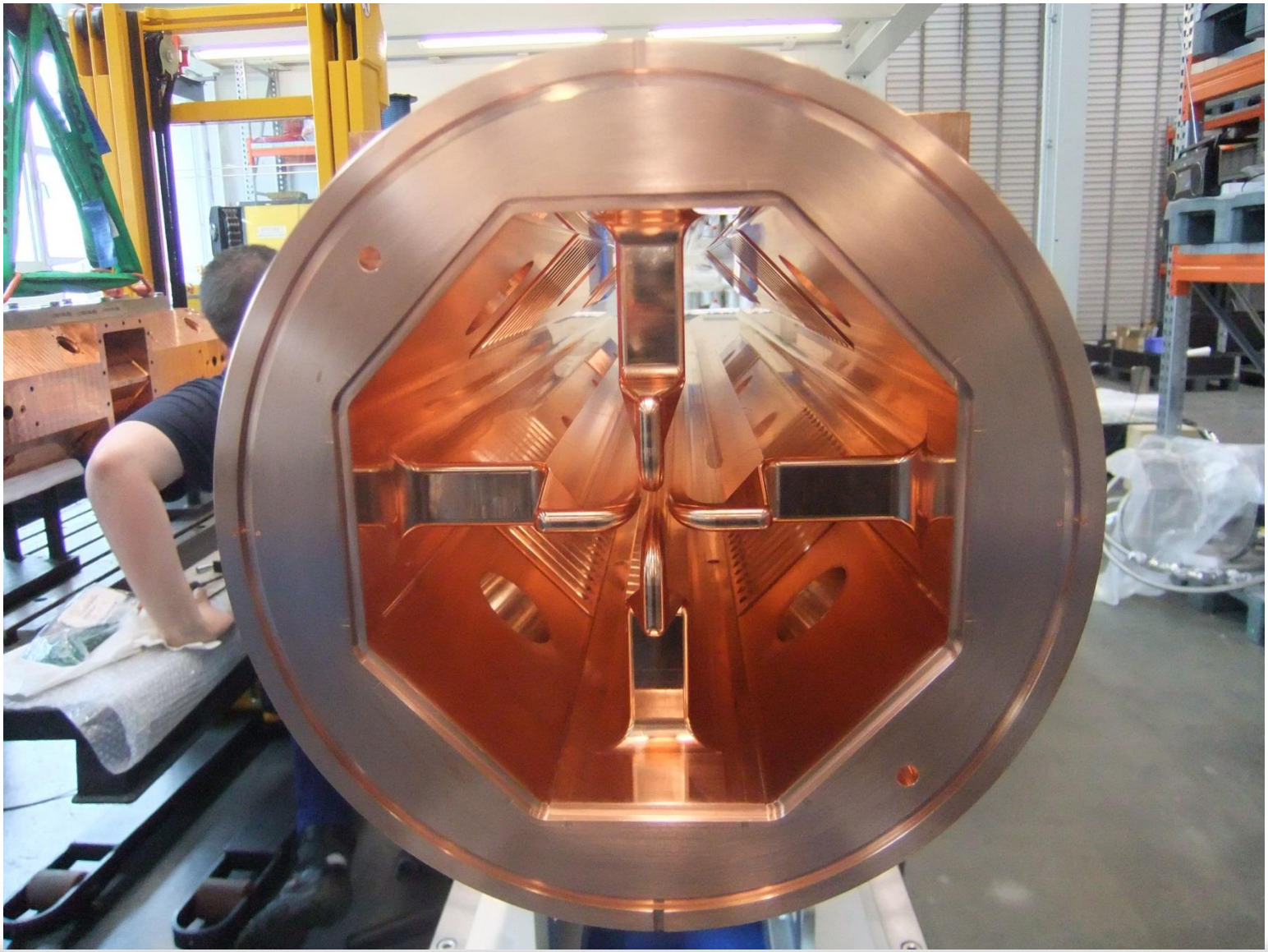
Vacuum in existing RFQ

- Gas load from the ion source: 35 scc/min
- Existing RFQ has 6 x 2000 L/sec cryopumps:
  - 2 pumps/module in modules 1 and 2, 1 pump/module in modules 3 and 4
- New spare will have improved vacuum pumping
  - 4x 1700L/sec turbos in module 1
  - 6x 2500L/sec cryopumps in Modules 2, 3, and 4

First Module Brazed (12/2012)



Assembling



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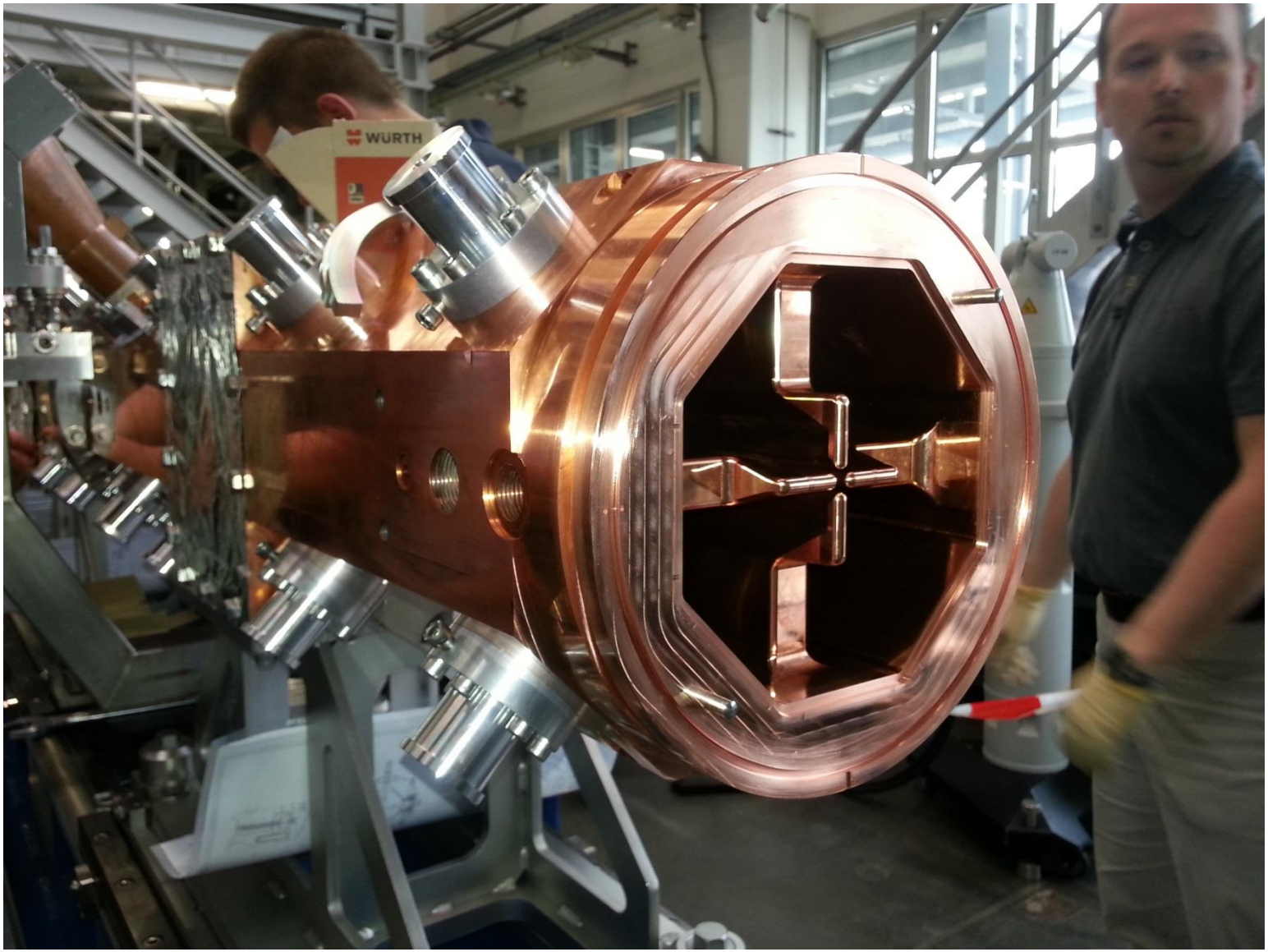

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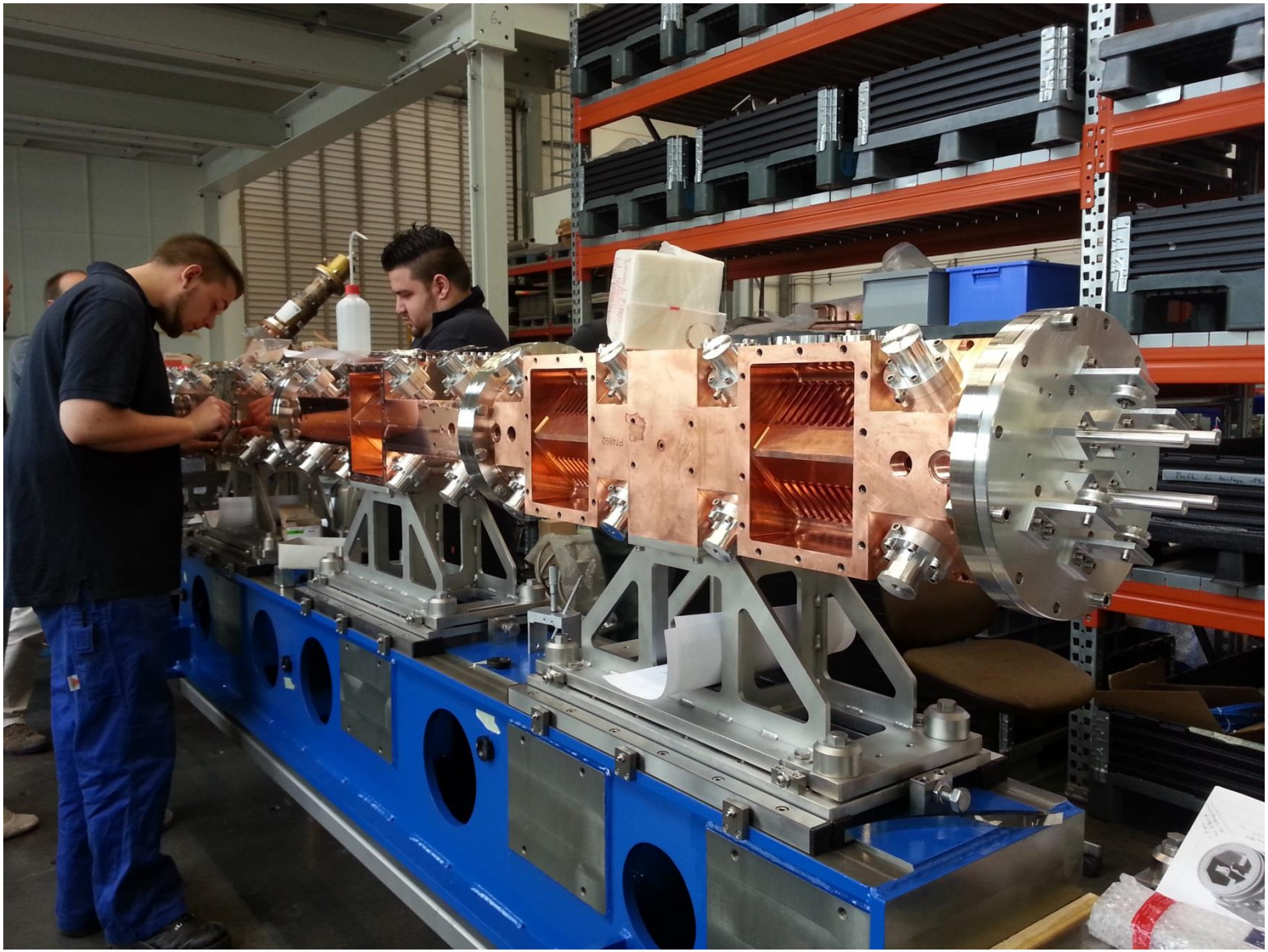


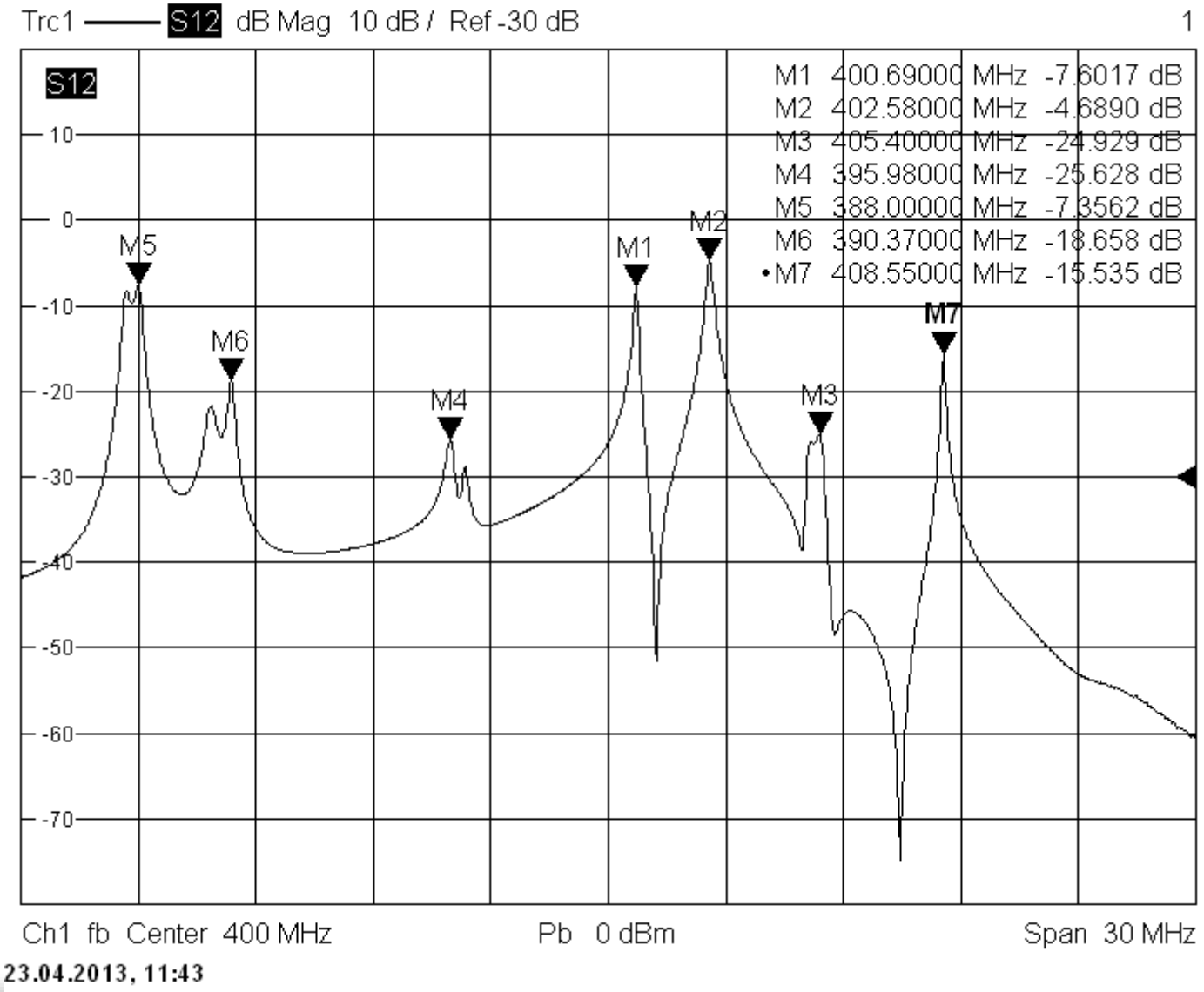
RF Tuning

- End-wall dipole rods are placed and adjusted for the mode spacing as calculated
  - Magnetic field bead-pull used to assure the gap field are set correctly
  - Aluminum adjustable slug tuners are installed
  - Tuner positions are determined for correct field by based on the bead-pull
  - Tuners are moved to improve the field distribution
  - Iterations of the above steps deliver convergence of the field within optimal field error (± 0.5 %)
- Copper slugs are cut to the lengths and installed to complete the tuning process
  - Result with the copper slugs are checked with bead-pull
- Field probe data recorded as the reference for future quick field check
- All specifications such as frequency, temperature, mode spacing, input power couplings are all interlaced in the tuning process

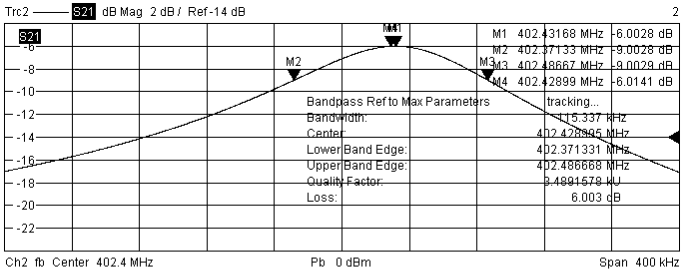
RF Tuning of Assembly

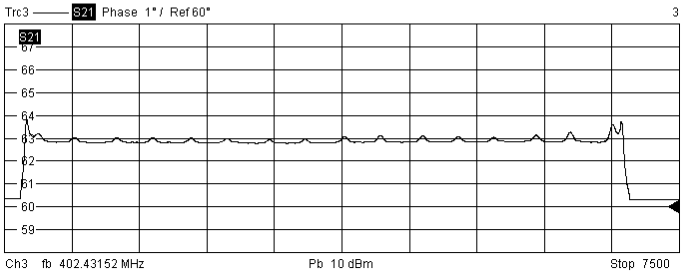
RF Mode Spectrum

Before tuning



Field Distribution after Tuning





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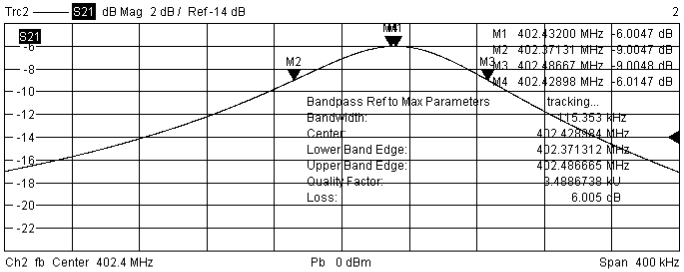
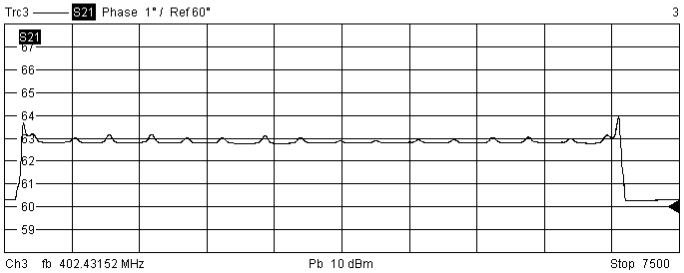
Q1





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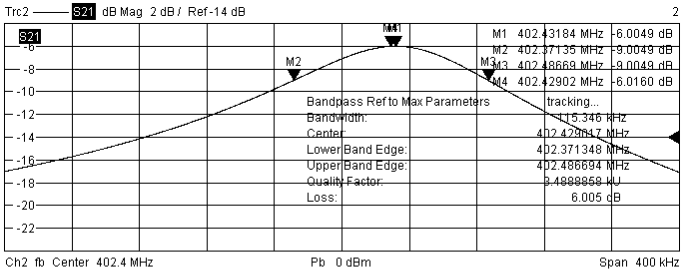

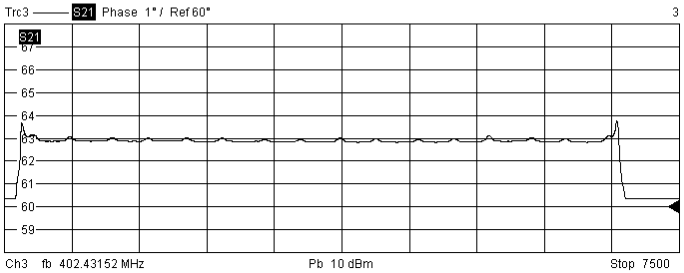

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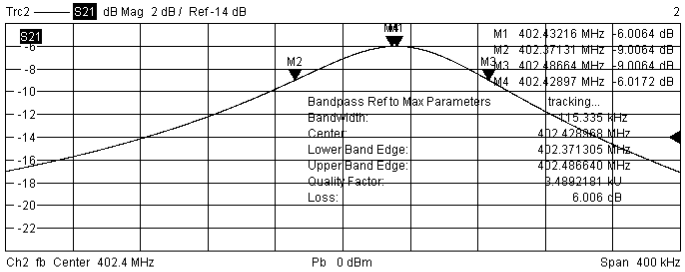
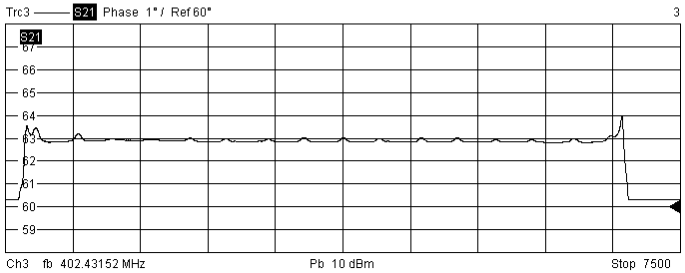
Q3





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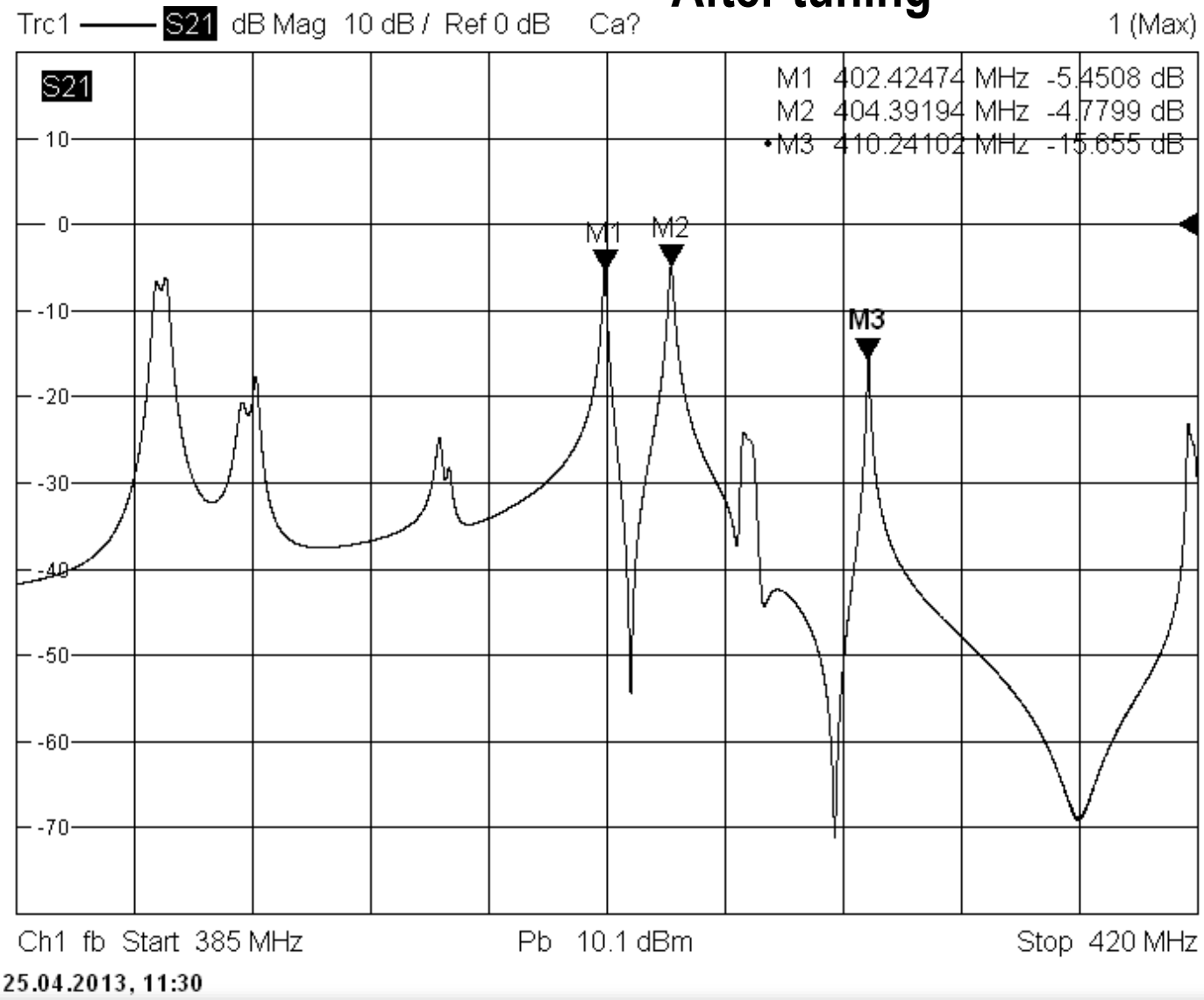
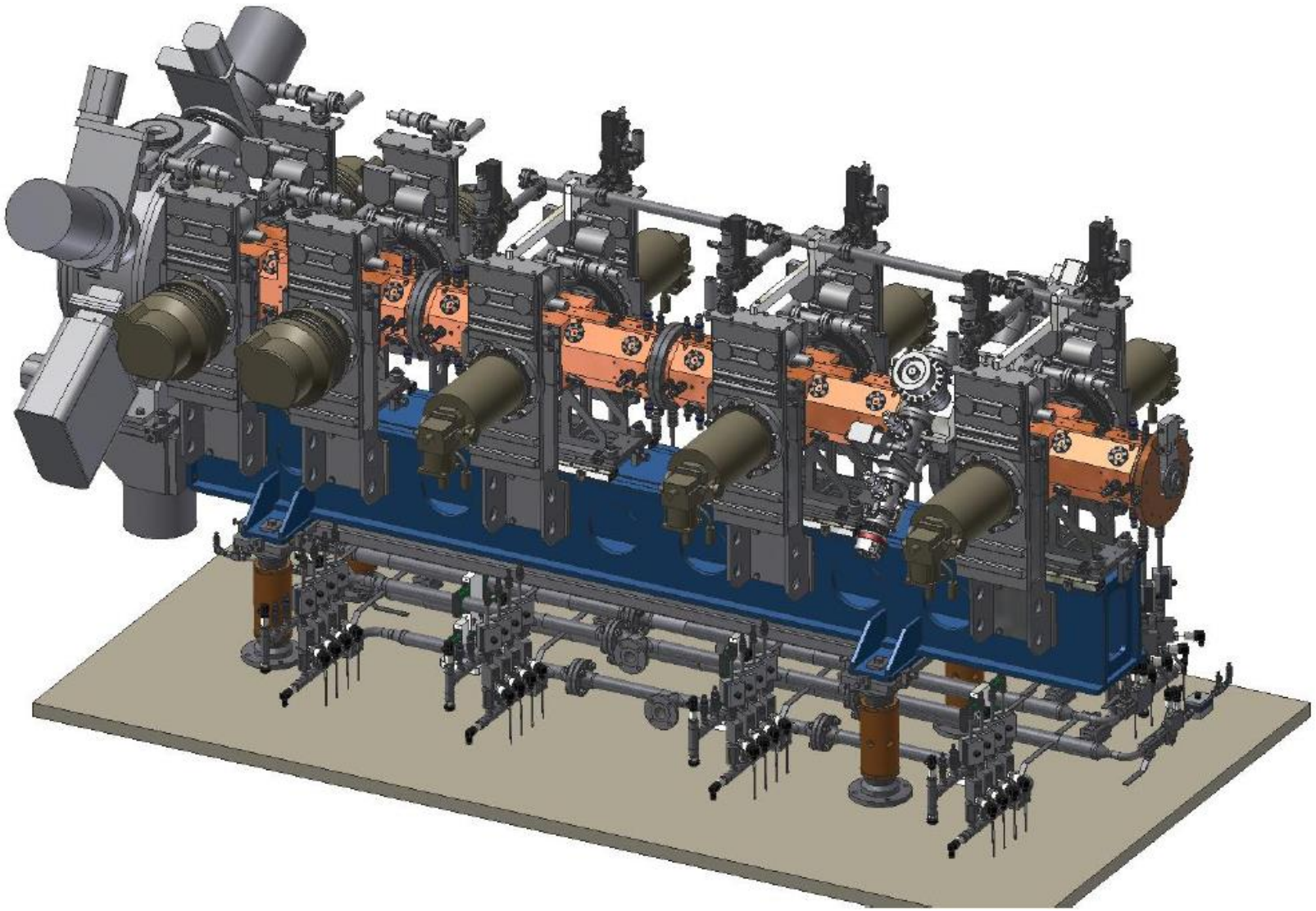
Q3

Mode Spectrum

After tuning



Final Assembly



Summary

- Manufacturing
  - Design/analysis were done for robust performance and operation
  - Machining and brazing completed successfully (April 19, 2013)
  - Assembling and RF tuning have been performed successfully (May 1, 2013)
  - Factory acceptance testing (June 2013)
- Shipping & delivery
  - Present goal for delivery is July 10, 2013
  - Has been delayed but quality of manufacturing of product shows performance
- Acceptance test (full RF power)
  - RFQ will be reassembled at the SNS
  - Completion expected by October 31, 2013)
  - Test setup near completion in RF Annex
- Full beam test
  - Test setup in RF Annex is to be used after installing ion source, beam dump, and diagnostics
  - Present plan is to complete the preparation by Dec 2013 and test through June 2014